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BOTRYTIS DISEASES OF GLADIOLUS

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THE PLANT DISEASE REPORTER SUPPLEMENT

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BOTRYTIS DISEASES OF GLADIOLUS[1]

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BOTRYTIS DISEASES OF GLADIOLUS

Charles J. Gould

INTRODUCTION

This article was originally prepared to facilitate discussion on the Botrytis diseases at the Gladiolus Disease Symposium sponsored by the North American Commercial Gladiolus Growers at Cleveland, January 14, 1953. It is primarily a literature review, but contains some unpublished data of the author and others. Data on the effects of relative humidity, temperature, and other factors on the gladiolus corm during storage are included because they are related to disease control.

IMPORTANCE

Although, according to Timmermans (70)[3], Sorauer described a Botrytis disease of gladiolus in 1898 and Ritzema Bos listed Botrytis on gladiolus leaves in 1914, the disease was practically unknown to gladiolus growers twenty-five years ago. Since that time, however, it has become increasingly important.

CORM ROT: Timmermans (70) stated that the disease suddenly became very harmful after 1937 in Holland. She attributed this to more favorable weather for the fungus, use of new and more susceptible varieties, and the lack of sufficiently good storehouses. Stofmeel (68) reported heavy losses in Holland in the winters of 1937/38, 1939/40, and 1940/41. Van de Pol and Flipse (71) stated that in 1948 Botrytis gladiolorum was still one of the limiting factors in gladiolus culture in Holland. However, a more recent Dutch publication (3) reported that better handling had resulted in a decrease of Botrytis attack.

Comments by English workers in 1950 to the writer indicated that it was the number one disease in their country. Wade (72) in 1945 in Australia listed losses of more than 50 percent of susceptible varieties during years favorable for the fungus. Drayton (31) in Canada reported in 1946 that prior to 1941 the only Botrytis seen was in corms imported from other countries. "During the last few years, however, several cases have been reported from Ontario by some of the larger growers and on each occasion the losses in several varieties have been severe."

The disease has also been very destructive in many areas of the United States. Baker (5) reported in 1948 that the Botrytis disease had become a limiting factor in gladiolus production in California. McWhorter (see 54) stated in 1948 that "...soft rot, due to Botrytis cinerea and possibly other species, has been the most destructive gladiolus disease in Oregon. Total loss from this disease has exceeded in one year the losses from all other diseases in five years." Hubert and Wheeler (40) in a summary of results of a disease survey of domestic-shipped corms by the Bureau of Entomology and Plant Quarantine during the winter of 1948/49, found B. gladiolorum once each in shipments from Florida, Maryland, Massachusetts, New Jersey, and New York, and in nine cases from Michigan. Three thousand, two hundred and eighty-one cases were involved in this survey and 451 cases were examined. No other species of Botrytis was found by them in rotted corms. Forsberg (35) stated that gladiolus growers in Kankakee County (Illinois) lost thousands of dollars from Botrytis rot during the winter of 1950/51.

In 1950 the writer (36) obtained estimates from scientists in several States and Canada of the average loss due to Botrytis corm rot. These ranged from a trace in Michigan and upstate New York, 0.4 percent in Florida, 1 percent in New Jersey, 1.5 percent in North Carolina and British Columbia, to 3 percent in western Washington.

LEAF AND FLOWER BLIGHT: Several epiphytotics of leaf blight have been reported in various areas of the United States, especially Florida and coastal areas of southern California and the Pacific Northwest. Magie (50) estimated that the combination of Botrytis and Curvularia alone on leaves and flowers was responsible for a million-dollar loss in the United States in 1950.

Over the United States as a whole, flower infection is probably of more economic importance than is corm rot. The former is particularly serious in Florida where millions of spikes are shipped to northern markets every year. The cut spikes may exhibit no symptoms before packing, but infection progresses rapidly under the cool moist conditions in hampers shipped in refrigerated cars or trucks, leading to considerable dumpage at destination. As an example,

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[3] Numbers within parentheses refer to Literature Cited.

Nelson (58) stated that "... during the winter of 1947, certain light-colored varieties were boycotted on the Chicago market for a time while Botrytis blight was ruining those sent to market. The spotting developed in transit..." According to Bald (13) the neck rot phase is common in southern California during autumn, winter and spring under certain conditions.

Sufficient reports are available to indicate that the Botrytis disease probably exists in every area of the world where gladiolus is grown. They also indicate that severe attacks are limited, presumably owing to climatic conditions, and that the leaf blight phase may occur (as in Florida) without appreciable corm rot. Conditions relating to this will be described later.

THE ORGANISMS

Of the several species of Botrytis that have been found on gladiolus, probably B. gladiolorum and B. gladioli have been listed most frequently. The status of these two was described as follows by McClellan, et al. (54):

"Klebahn (41) described Botrytis gladioli Kleb. in 1930, and Timmermans (70) described B. gladiolorum Timmermans in 1942. Botrytis gladioli differs from B. gladiolorum mainly in the shape of the conidia which are long and narrow, averaging 10.4 µ x 4.7 µ, whereas conidia of the latter species are ovoid to subglobose and average 15 µ x 10 µ. Conidia of the Botrytis isolated by Moore (57), by Hawker (38), by Dodge and Laskaris (29), and by us correspond with those of B. gladiolorum (conidia from our isolates average 14.7 µ x 9.8 µ). Wade (72) called the Botrytis he studied B. gladioli, but presumably it was B. gladiolorum since his spore measurements and other morphological evidence agree with Timmermans' organism rather than with Klebahn's. Miss Hawker (38) considered her isolates to be strains of B. cinerea but the spore measurements she gives agree with Timmermans' B. gladiolorum. Dennis and Wakefield (21) described the perfect stage of Botrytis isolated from a gladiolus corm by W. Buddin as Sclerotinia Draytoni Dennis and Wakefield. They described the conidia as narrowly elliptical and 8-16 µ x 5-7.5 µ. These spore measurements agree with those of B. gladioli. Drayton obtained single ascospore cultures from Buddin and in a personal communication to us states, 'After making a number of measurements, Dr. Groves and I are of the opinion that Botrytis gladiolorum is the conidial stage of Sclerotinia (Botryotinia) Draytoni, and that this is the fungus responsible for the early-storage decay.' Parallel inoculations of Picardy gladiolus corms with one of Buddin's isolates (163-K) obtained by us from Drayton and with one of our own isolates (213-D) have given similar infection. ...Botrytis gladioli is poorly described and no mention is made of its effect on the plant. Timmermans points out that Klebahn mounted his spores in glycerine and his measurements might have been greater had the spores been mounted in water."

Peiris (59) stated that the descriptions of isolates of Botrytis from gladiolus by previous workers (except Klebahn's B. gladioli) were all similar to B. gladiolorum and were probably that species. Peiris's isolates of Botrytis from diseased gladiolus were in the proportion of 99 to 19 for gladiolorum and cinerea, respectively. Seventy-nine percent of the cinerea isolates but only 45 percent of the gladiolorum isolates were from above-ground parts. The only species listed by Weiss and O'Brien (75) in their Index of Plant Diseases in the United States are B. gladiolorum recorded from California, Florida, Massachusetts, Maryland, Michigan, New Jersey, New York, Oregon, Washington, Wisconsin, and Alaska, and B. elliptica from Washington. Schmidt (66) identified the Botrytis causing a corm rot in Austria as B. gladiolorum.

MacLean reported (46) finding Botrytis gladiolorum, B. gladioli, B. elliptica and B. cinerea on gladiolus in Washington in 1947. B. cinerea has been reported on gladiolus by other workers. McWhorter (56) stated in 1939 that a strain of B. cinerea attacked maturing gladiolus foliage in a field near Portland and commented that "... this is the first record we have of Botrytis attacking gladiolus foliage in Oregon." He (see 54) also referred to the corm rot in Oregon in 1948 as being caused by B. cinerea and possibly other species. Weiss (74) stated in 1940 that a rot of gladiolus corms grown on Long Island was apparently caused by B. cinerea. Dimock (28) said that an epiphytotic of leaf blight and flower spotting in Florida in 1940 was apparently caused by a Botrytis of the cinerea type. Timmermans (70) isolated B. cinerea only once (that time from blooms).

B. cinerea was found by MacLean (46) in 1947 on 62 ornamental hosts, including gladiolus. Isolates of this species from 17 different hosts were able to infect the above-ground parts of gladiolus. Only one isolate was incapable of causing infection. Seedling gladiolus were most susceptible. MacLean summarized his tests with B. cinerea as follows: "Each of the hosts tested was parasitized to some degree by at least one of the eighteen collections of Botrytis

cinerea used in the tests. Many of the collections of Botrytis cinerea proved to be very pathogenic on a great variety of hosts." ... and concerning gladiolus, "The results of these experiments add further proof to the statements made by many workers in the field that Botrytis cinerea is very possibly responsible for much of the above-ground spotting of the plants in the field."

In comparative tests Peiris (59) found that B. gladiolorum was more pathogenic to gladiolus than B. cinerea but that the latter was capable of causing some infection. In comparable tests with the two species on roots of rutabaga and turnip and corms of gladiolus, B. cinerea was definitely more pathogenic to the former and B. gladiolorum to the latter.

Botrytis elliptica was found by MacLean (45) causing leaf spots on gladiolus in western Washington in 1947.

MacLean (46) made several cross-inoculation tests with 11 different species of Botrytis on 12 types of bulb or corm hosts. The results on gladiolus are contained in Table 1. Flowers were susceptible to attack by many species, but leaves, stems, and even corms were affected by species other than those normally occurring on gladiolus. In general, those species that had been found naturally occurring on gladiolus (B. gladioli, B. gladiolorum, B. cinerea, and B. elliptica) produced the most damage.

On the basis of the experiments and observations by MacLean and others, it would appear that generally most corm rot and much of the leaf and flower spotting is caused by B. gladiolorum, but that B. cinerea may occasionally be responsible for some damage to leaves and flowers. The position of B. gladioli, B. elliptica, and other species is uncertain but probably minor.

HOSTS OTHER THAN GLADIOLUS

Timmermans (70) isolated Botrytis gladiolorum from crocus bulbs, spots on Freesia leaves, and Montbretia plants.

A summary of MacLean's data (46) (Table 2) indicates that B. gladioli and B. gladiolorum can attack a number of other bulb or corm hosts under certain conditions. The flowers were most susceptible in his tests, but sometimes leaves and even corms and bulbs were affected.

For comparative purposes in this discussion, brief descriptions (from MacLean, 46) of the following Botrytis species are included:

Botrytis elliptica ... "The conidiophores of Botrytis elliptica are numerous, 1-3 mm. long, branched, with pale brown walls, and they bear at their tips clusters of elliptical, hyaline, later sometimes pale brown conidia averaging 24 x 16 µ; with a range of 20-25 x 14-16.5 u (16-34 x 10-24 µ according to Westerdijk and van Beyma). ... The sclerotia are somewhat irregular in size and shape, and shining black..."

Botrytis gladioli. "The conidiophores are up to 2 mm. long, dark brown below, and swollen at the tips into comparatively small ampullae bearing jagged or toothed sterigmata from which cylindric-ellipsoidal conidia measuring 8-15 x 3-6 µ (Av. 10.4 x 4.7 µ) are abstricted. . . The sclerotia are whitish when young, later become gray and finally black. They are often aggregated into coralloid masses on top of the corm..."

Botrytis gladiolorum. "The conidiophores are brown in color although not a dark brown, lighter at the top, bearing conidia on ampullae situated along the conidiophores. The conidiophores are about 20 µ thick at the base. The conidia are hyaline, smooth, oval to egg-shaped, sometimes nearly round, single-celled, and measure 12-15 x 9-12 µ (Av. 15 x 10 µ). The sclerotia are small to large and are black..."

Botrytis cinerea. "The conidiophores are slender, constricted at the septa, gregarious, simple or sparsely branched, erect and cinerous. They bear globose pale conidia that measure 4.6-7.5 x 7.5-13.1 µ. The sclerotia range from dark gray to black and vary in size from very small up to one-quarter inch in diameter."

Table 1. Results of cross-inoculation studies by MacLean (46) with Botrytis species other than B. cinerea on gladiolus:

Botrytis species	Inoculations on: Flowers	Cut flower stems	Leaves and stems	Corms: (soil inocu- lations
B. tulipae	0	2	2	0
B. narcissicola	2	T	T	0
B. elliptica from Colchicum sp.	2	3	3	0
B. elliptica from Lilium sp.	3	3	3	1
B. gladioli	2	2	2	3
B. gladiolorum	4	3	4	3
B. croci	4	0	T	0
B. galanthina	4	0	0	0
B. hyacinthi	2	0	0	0
B. cinerea f. convallariae	4	0	2	T
B. convoluta	0	0	0	2
B. polyblastis	0	0	0	0

0 = no symptoms, apparently immune
T = resistant, only a few spots present
4 = highly susceptible
1, 2, 3 = intermediate degrees of susceptibility

Table 2. Results by MacLean (46) of inoculation studies with Botrytis gladioli and B. gladiolorum on various hosts:

Host	B. gladioli				B. gladiolorum			
	Portion of plant inoculated				Portion of plant inoculated			
	Flowers	Flower stems	Leaves and stems	Corms: (soil inocu- lations)	Flowers	Flower stems	Leaves and stems	Corms (soil inocu- lations)
Tulip	2	T	T	1	2	2	1	3
Narcissus	2	0	T	2	3	1	1	3
Iris	2	-	T	0	2	-	1	0
Lilium	0	-	0	2	1	-	0	T
Gladiolus	2	2	2	3	4	3	4	3
Hyacinths	2	-	0	0	2	-	0	2
Crocus	2	-	T	2	4	-	T	1
Convallaria	0	-	T	1	0	-	T	0
Colchicum	0	-	0	0	0	-	0	0
Scilla	2	-	0	2	2	-	0	2
Muscari	1	-	0	2	2	-	0	0
Freesia	2	-	T	T	2	-	T	0

0 = no symptoms, apparently immune
T = resistant, only a few spots
4 = highly susceptible
1, 2, 3 = intermediate degrees of susceptibility

PHYSIOLOGY OF BOTRYTIS GLADIOLORUM

According to Timmermans (70) the growth of the fungus on agar was weak at 37° F.,[4] ceased at 86°, and was optimum between 68° and 72.5°. She also ran pH tests on prune agar (between 4 and 8.5) and found strongest growth between 5 and 5.5.

Peiris (59) found the best medium for sporulation of B. gladiolorum to be a decoction of gladiolus leaves and glucose-peptone, kept in good light and under moderate drying conditions.

SYMPTOMS

LEAVES: Leaf spots show a wide variation in size and shape (Fig. 1, 2). They may be oval or circular, pinpoint in size, or large (over 1/2 inch) and irregular. They usually have a brown or grayish-brown center that is often covered with a gray mass of spores. The margin of small spots is usually definite and dark brown, reddish-brown, or even red, but large spots more often have an indefinite margin. Large spots on leaves and stems may cause a yellowing and eventual death of the terminal portions.

Experiments by MacLean (46) indicate that infection of gladiolus leaves by the different species of Botrytis results, in general, in similar symptoms. However, the common parasites

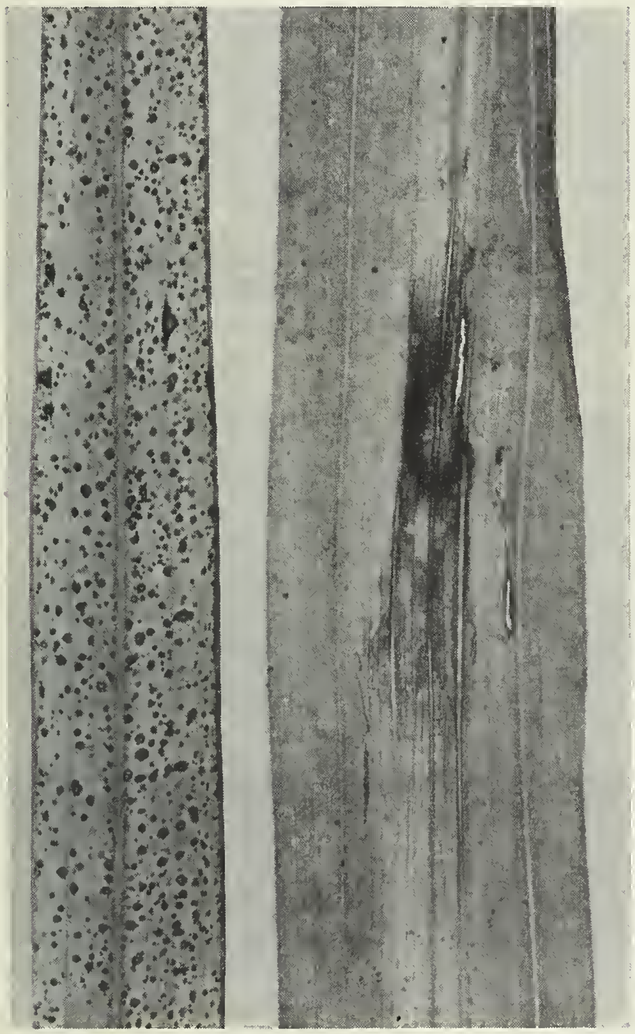

FIGURE 1. Different types of leaf spots on gladiolus caused by Botrytis gladiolorum.

FIGURE 2. Infection of gladiolus leaves and flower spike by Botrytis gladiolorum. Note decay of margins of petals.

[4] In order to facilitate comparisons, all temperatures, including those in quoted material, have been converted to °F.

such as B. gladiolorum were capable of producing the largest spots whereas smaller spots were generally due to the uncommon species such as B. tulipae.

The variation in size, shape, and color of the leaf spots have been confusing. MacLean's results may explain some of the variation. In addition, McClellan, et al. (54) have demonstrated that insofar as B. gladiolorum is concerned much of the variation is related to temperature during and after infection. Thus, at 35° the spots were only pinpoint in size; at 40° and 45° they were also small but tended to coalesce and become larger after six to ten days; at 55° and 65° the lesions increased more rapidly in size; at 75° infection was slight.

Sometimes it is difficult to isolate the fungus from the small lesions that fail to increase in size. Bald (7) has stated that: "On the leaves of gladioli Botrytis produces dead spots of two kinds, small spots and big spots. In each of the small spots, one or two fungus threads of hyphae become established at the center and immediately under the leaf surface. These hyphae can be killed by warm weather, and often are: thus weather may fight for the grower as well as against him." Also, according to Bald (13) leaves may resist infection by the precipitation of gum in affected cells during periods of warm dry weather.

In the tests by McClellan, et al. (54), already mentioned, considerable infection occurred within 24 hours after the plants had been inoculated and held in a moist chamber. Within 120 hours the leaves were completely killed. Magie (47) has stated that a 13-hour humid period (furnished by dew) was sufficient to allow infection.

Bald (8) has recently published some interesting observations and experiments on the method of infection by Botrytis gladiolorum. He found that drops of water may be exuded through the stomata of gladiolus leaves. This occurs when the atmosphere is cool and humid and the soil is warm and moist. On vigorous plants in damp soil under highly humid conditions the droplets may even overflow, forming a heavy deposit of drops and films of water. On plants in dry soil the droplets are very small or lacking. The droplets readily permit the germ tubes of the fungus to pass into the stomata and infect the leaf. When leaves remain continuously wet the germ tubes enter the leaf directly through the cuticle.

Magie (47) indicated that leaf infection of Picardy and Maid of Orleans varieties was greater in those plots receiving normal fertilization than in those receiving low nitrogen or no fertilizer. He also mentioned in a recent letter (December 9, 1952) that plants infected with a virus are more susceptible than are healthy plants.

FLOWERS: Flowers are very susceptible to attack. The infection often begins as a small water-soaked spot, usually near the edge of the petal (Figs. 2 and 3). The spot may enlarge rapidly and become rather slimy. The fusion of several spots rapidly converts the flower into a drooping mass of tissue that is soon covered under moist conditions with a gray mass of spores. The color of these spots has been reported as varying from white (watersoaked) to brown, and sometimes white with a light brown or violet-colored border.

Magie (47) stated that a six-hour wetting period was sufficient for petal infection and that the infection may appear within 14 hours after inoculation. In 1948 he found some infection of open florets in Florida as late as May when the minimum temperatures averaged 65° and the mean temperature was 76° F for the month.

NECK: If infection occurs at or near the soil level, it may progress inward through the leaf bases and rot the stem. This often results in a gradual yellowing and eventual death of the upper part of the plant. Under moist conditions the rot is wet and brown, with the outer surface often covered with a gray "fuzz" of spores. Under dry conditions the area is dark brown and firm with a definite margin, and lacks the spore fuzz. The outer leaf bases may become shredded, somewhat as with dry rot but without the minute black sclerotia of the dry rot fungus. This neck infection may come from diseased corms, in which case it usually appears soon after the plants emerge; or it may come from air-borne spores, with the time of infection dependent upon suitable climatic conditions. According to Bald (13) neck-rot infection very seldom comes from infested soil.

Bald (7) has stated that: "The most serious aspect of Botrytis neck rot is not the killing of a few plants; it is that affected plants provide a unique source of spores, largely protected from sprays, able to persist during weather unfavorable to the disease. The importance of neck rot plants in a crop is far greater than their numbers. ... A single neck rot plant can produce millions of spores -- we have made estimates of the numbers of spores present at one time on a neck rot plant, and have obtained figures between half a million and several million. Such numbers of spores can be produced by cool humid conditions on a previously quiescent neck rot lesion in 24 to 48 hours."

FIGURE 3. Lesions caused by Botrytis gladiolorum on a light-colored flower (left) and a dark-colored flower (right) of gladiolus.

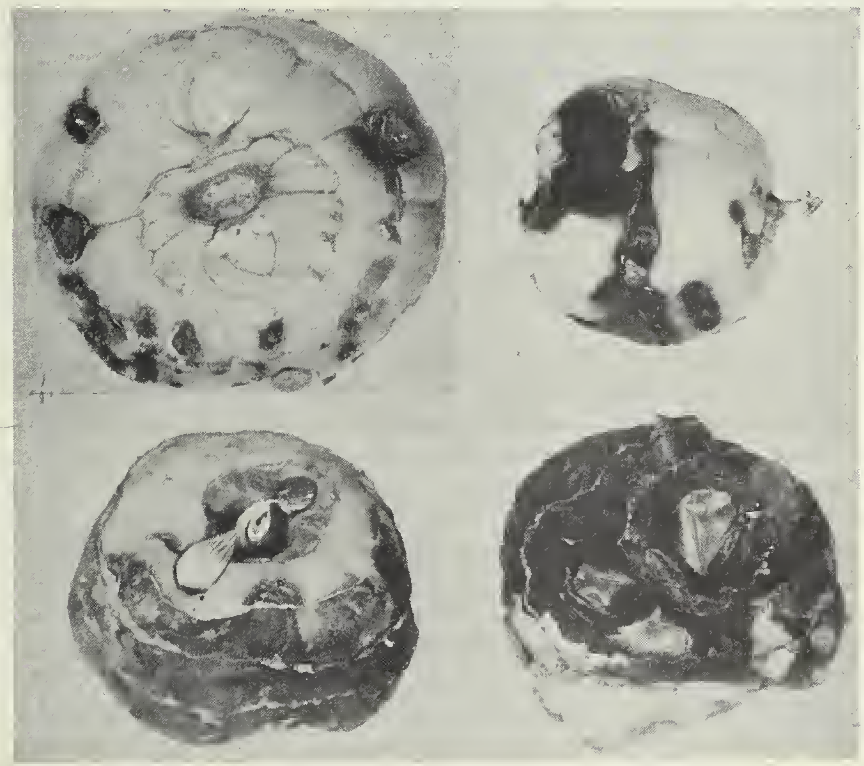

FIGURE 4. Gladiolus corms with different degrees of infection by Botrytis gladiolorum.

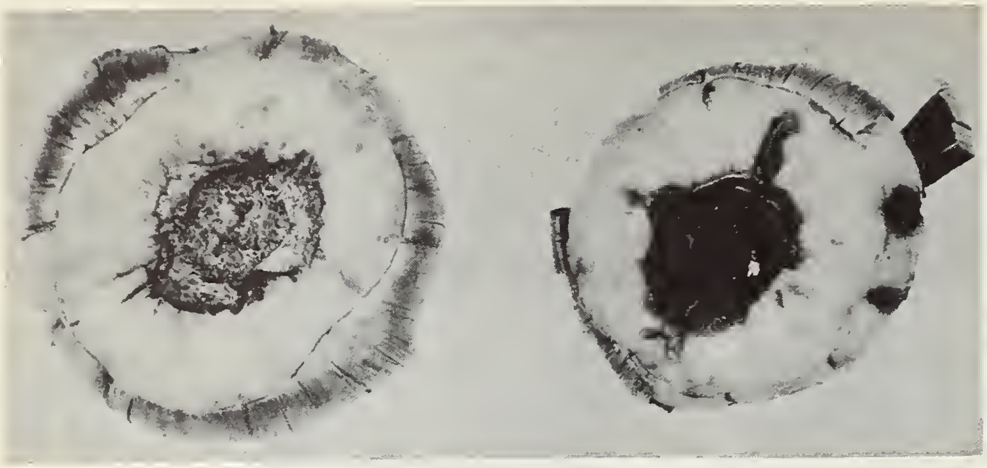

FIGURE 5. Core or "doughnut" type of gladiolus corm rot. (Botrytis gladiolorum).

FIGURE 6. Cross section of gladiolus corm affected with spongy type of decay caused by Botrytis gladiolorum.

CORMS: Several types of symptoms observed on corms (Fig. 4) were formerly attributed to different causes but are now recognized as different expressions of attack by the same organism. The earliest stages of infection may easily be overlooked. The different symptoms are: (a) occasional brown discoloration of basal plate; (b) one or many brown vascular bundles extending up to the stem area; (c) core partially or completely rotted, with or without surrounding tissue also rotted, and with or without infected brown vascular strands radiating to the surface (Fig. 5); this rot may result in the core falling out or becoming completely decomposed, leaving a doughnut-type condition); (d) light, watersoaked, straw-colored, greenish brown to dark brown spots on the surface, with a watery, greenish indefinite margin or with a definite brown, and usually sunken margin (arrested lesions are usually brown, sunken and firm); and (e) a general spongy decay (Fig. 6).

The decay varies from soft to rather fibrous and firm, apparently depending upon moisture and temperature. Under certain conditions, the husks may appear normal, but the corm underneath will be completely rotted. At an early stage water can easily be squeezed from such a corm, but later it gradually dries into a mummy or disorganized mass of dead tissue. Under optimum humidity conditions the fungus produces a mass of white, cottony mycelium underneath the husk. Sometimes, but not always, black sclerotia are formed, and less often conidia. The husks may be brown and split. When infected corms are planted, some produce healthy shoots while others die or give rise to weak, yellow shoots that often die. Baker and Sciaroni (6) and others have stated that the fungus will grow from corm to corm in storage.

Hawker (38) observed that when the old stem base could usually be lifted out leaving a clean

depressed scar the corms were healthy, but when this could not be done the corms often developed core rot later, especially with the varieties Picardy and Yvonne.

Bald (10) found that when remnants of tissue from the parent corms remained attached to the basal scars of daughter corms at normal cleaning time the probability was high that Fusarium or some other pathogenic organism had penetrated through such basal scars into the new corms.

The different types of corm rot were shown by McClellan, et al. (54) to be at least partially caused by temperature differences. Corms held at 45^{o} F or warmer had darkened husks and dark rotted portions, whereas at 35^{o} the husks and rotted portions were lighter in color and the rot was not so well defined.

Histology of Infected Area -- Bald (10) found considerable varietal difference in the reaction of corms to invasion by Botrytis. He stated that: "On the corms of some, e. g. Lady Jane..., large dark brown surface blemishes occurred and there was relatively little penetration of the tissues. Mycelium was mainly subcuticular, several layers of cells were killed by toxic action, and internally a periderm layer was formed. Vascular invasion was often restricted. In other varieties, e. g., Helen Mayne..., vascular bundles and parenchymatous tissues were readily invaded, and the core often rotted out. Water-soaking of tissues at the margin was a regular feature of Botrytis lesions expanding through storage tissues in this and similar varieties."

Wade (72) stated that the Botrytis entered the corm along vascular bundles from either the cut stem end (most common) or through the old corm, but never through parenchymatous tissue. Timmermans (70) apparently also found most penetration occurring through the cut stem end but stated that spots developed on the upper corm surface that were not always connected with a rotted core. This is supported by Hawker's (38) observations. Drayton (31) believed that attack could take place at any point, but perhaps most frequently in the region of the basal plate. Peiris (59) concluded that infection occurred primarily either through the cut stem end or through the scar if the stem was removed, but that some could take place through the old corm or basal scar. Bald (10) found that the most frequent points of origin of lesions on the larger corms appeared to be the leaf scars and the bases of flower stalks. In inoculation tests Hawker (38) obtained more infection of wounded than nonwounded corms and more at the neck or base than at the side. Peiris (59) also found that wounded corms were more susceptible than unwounded ones. Wade (72) did not believe that soil infection was important but Hawker (38) found that some apparently could occur.

Bald (10) has reported that: "In both foliage and corm tissues Botrytis mycelium was often subcuticular..., and in superficial lesions might not penetrate noticeably between the living cells. Where discoloration followed the vascular bundles, long stout hyphae were found running parallel with the bundles along the walls of parenchymatous cells rather than internally along the vessels. As breakdown of these tissues occurred, Botrytis mycelium ramified and penetrated the vessels. Botrytis often grew superficially between enfolding leaf bases, particularly under wet conditions. This sort of mycelial growth probably accounted for numerous infections in vegetative buds of corms held during winter on piled-up trays in the field. Lack of dormancy under cool conditions allowed some development of vegetative buds on the corms immediately after digging. The incidence of bud lesions suggested infection from the enfolding leaf scales, either by penetration into the meristematic tissues, or at the junction between meristematic tissues and the storage tissues of the corm. Having penetrated, the mycelium frequently progressed along the vascular bundles leading inwards from the buds..."

Wade (72) described the histology of corm rot as follows: "In active lesions the middle lamella of the cells of diseased parenchymatous tissue had been destroyed and the cells greatly distorted. The cell contents showed no definite structure but contained an accumulation of starch granules. At the edge of diseased lesions there is usually a sharp line of demarkation between the almost completely disorganized diseased tissue and the surrounding normal tissue... The mycelium of the fungus was abundant in the disorganized tissue and sometimes penetrated to a depth of several cells into apparently normal tissue.

"In some sections, however, there was a layer of cells containing a reduced number of starch grains, between the infected tissue and the normal tissue... The infected tissue contained an accumulation of starch granules and there was no suberinized layer at the edge of the healthy tissue. It therefore differed from the histological structure of arrested lesions, which will be described later.

"As previously stated the disease travels along the vascular bundles. The phloem tissue of the infected bundles is rapidly disintegrated and later the wood vessels are attacked and destroyed...

"Infected tissue of corms, in which the disease has been arrested differs in several respects

from those just described. The severely infected tissue is similar to that in actively growing lesions but no starch granules are present. It is surrounded by a layer of cells about 1 to 2 mm. wide, which have practically no cell contents and very few starch grains, but the cell walls do not show marked distortion. This layer of cells only contains a few hyphae of the organism. At the edge of these cells there is a layer of rectangular suberinized cells and beyond that the tissue is normal..."

Timmermans (70) stated that even the diseased vascular bundles may be surrounded by corky tissue.

Wade (72) found that the capacity of Botrytis to utilize pectin explained the rapid disorganization of infected tissue. Additional results of other tests on the chemistry of the host and physiology of the fungus are reported in his article and that of Timmermans (70).

Effect of Temperature on Infection -- The optimum temperature for infection of freshly harvested corms was 35° F in tests by McClellan, et al. (54). Some infection occurred at 45° but none at 55°, 65°, or 75°. Drayton (31) found that infection was more rapid at 38° to 45° than at higher temperatures. However, he was able to obtain some very small lesions on newly dug corms at 60°. Recently dug corms, inoculated with Botrytis, were completely rotted within ten days at 40° in his tests. Simmons (67) has stated that "while the growth rate increased regularly from 32 to 62° F., [on agar] the progress in the corm reached a maximum at 45° and fell off from that point until at 62° it was little higher than at 32°." Peiris (59) obtained most infection at 59° (88 percent); less at 41° to 50° (50 percent); and least at 68° to 77° (10 percent).

There is a marked difference between the optimum temperature for infection and that for growth of the fungus in culture. This attributed to the formation by the corm of the suberin and cork layers that wall off the infection. These will be discussed in a later section.

Relation of Time of Digging to Corm Rot -- In areas such as western Washington Botrytis rot is more prevalent on corms dug late in the season than on those dug early. Thus in experiments by Gould (54) at Puyallup in 1946, the loss from Botrytis of corms dug at two-week intervals was as shown in Table 3.

Table 3. Effect of digging date on percentage corm rot.

Date Dug:	Sept. 24	Oct. 8	Oct. 22	Nov. 5	Nov. 26	Dec. 16
Percent Loss:	2.4	2.9	4.5	4.6	14.6	27.6

The rainfall increased and the temperature decreased from September 24 to December 16. A similar test by the writer in 1949 gave the results shown in Table 4.

Timmermans (70), Wade (72), and Hawker (38) also found that early digging resulted in more healthy corms. These results are probably based upon the joint action of temperature and moisture as discussed by McClellan, et al. (54).

Since Botrytis leaf blight requires cool, moist conditions for development, it is usually limited in range in the United States. Such conditions commonly coincide with gladiolus growing along the Oregon and Washington coasts in the fall, in southern California in April and May, and in Florida in the winter. Occasionally they occur elsewhere, sometimes in extreme form.

Serious attacks of corm rot are less common, being restricted usually to the Pacific Coast areas but occasionally occurring elsewhere. The corm rot stage seldom occurs in Florida since temperatures there at digging time are usually high enough to promote rapid curing. Recently some severe losses, particularly to small growers, have occurred in the northeastern States. Perhaps the importance of this disease may have been underestimated in the past because of confusion of symptoms with the common Fusarium rot. Comments at the Cleveland symposium indicate that it rates as the number two gladiolus disease in the United States.

SUSCEPTIBILITY

Commercial growers and scientists have frequently observed and occasionally reported the variation in susceptibility of different gladiolus varieties to leaf blight and corm rot. It seems most appropriate to describe the variation as a degree of susceptibility rather than of resistance, since all varieties can apparently become infected under optimum conditions. Varieties that are

Table 4. Effect of digging date on percentage corm rot and yield.

Digging date	Percent* corms rotted	Total weight harvested	Total No. 1 corms
Sept. 13	8	26.3 lbs	222
20	6	26.5	224
27	30	34.1	309
Oct. 4	77	36.2	359
11	94	35.6	355
18	61	40.7	369
25	98	37.3	344
Nov. 1	99	45.5	426
8	99	41.2	373
15	99	43.0	372

* All corms except those of October 18 placed immediately after digging in a cool room (below 50°) to facilitate rotting. Those of October 18 were accidentally heated at 60° for one week, thus resulting in less rot.

Table 5. Susceptibility of Gladiolus varieties to Botrytis leaf blight.

Most Susceptible

Algonquin	Grand Opera	Miss Wisconsin	Rosemaid
Amulet	Hindenburg's Memory	Myrth	Rose O'Day
Annamae	Intruder	Nana	Rose Red
Autumn Gold	Jules Amott	Nowadays	Rose Morn
Bernece	Junior Miss	Nugget	Rosy Red
California	King Bee	Oriental Pearl	Royal Garnet
Candy Splash	King's Ransom	Pacifica	Ruby Red
Carrara	Lady Boo	Paradise	Sahara
Cherry Jam	Lady Jane	Parma	Seedling 1940 #11
Chief Multnomah	Lancaster	Patty Berg	Snow Princess
Connecticut Yankee	Lidice	Paul Revere	Snowsheen
Corona	Maid of Orleans	Pfitzer's Masterpiece	Surfside
Cover Girl	Manchu	Phoebe	Tecumseh
Discovery	Margaret Fulton	Piccolo	Valedictory
Eglantine	Margo	Pink Charm	Vela
Elizabeth Maier	Marimba	Pink Radiance	Vista Bonita
Errey's Scarlet	Marion Pearl	Prestige	Vredenburg
Essa Marie	Marjorie Decou	Purple Supreme	White Gold
Exemplar	Mary Elizabeth	Rampart	White Satin
Flora Farmer	Maytime	Red Bank	Will Scarlet
Fuchsia Maid	Mercury	Red Plush	Wings of Song
Golden Cup	Minstrel	Regent	Wolverine State
Golden State	Miss Cobbleskill	Rio Rita	Yangtze
Graff Seedling #15	Miss Vermont	Robinson Crusoe	

Least Susceptible

Alchemy	Debutante	Mamie	Sea Foam
Sotearoa	Donna	Marqueeta	Silvery Teton
Barbara Jane	Elegy	Niels M. Jensen	Snow White
Bethlehem	Evenglow	Oregon State	Spotlight
Capsicum	Giant Nymph	Pink Paragon	Sun Spot
Chamouny	Gratitude	R.B.	Susannah
Charmaine	Lavender Ruffles	Red Charm	Truelove
Convoy	Lins Seedling #388	Red Rascal	Valeria
Debonair	Malta	Rhoda	Winston

quite susceptible to the blight are not necessarily equally susceptible to corm rot, and vice versa.

A few years ago Magie released a list (48) of varieties with their susceptibility rating in Florida to the leaf blight stage. In Table 5 are listed the most and the least susceptible varieties, according to him. Recently he stated (51) that no variety has been consistently resistant to floret infection.

Timmermans (70) reported that Stofmeel listed the following varieties as very susceptible: Picardy, Mimmelstar, Poolijs, Betty Nuthall, Kassel, Flaming Sword, Roi Saleil, Jacoba van Beieren, and Mount Everest. Less susceptible varieties were Halley, Lilac Wonder, Red Emperor, and l'Immaculée.

Inoculation tests by Moore (57) indicated that Betty Nuthall and Pfitzer's Triumph were more susceptible to core rot than were Yellow Hammer and Halley. He observed severe infection of leaves of Red Emperor but only slight infection of those of Flaming Sword, Lady Boreel, and Halley.

Wade (72) found that Pelegrina, Red Lory, and Miss New Zealand (particularly) were more resistant to corm rot than Golden Goddess, Wolfgang v. Goethe, Gate of Heaven, and Picardy. However, Pelegrina suffered considerably from leaf infection, whereas Picardy had the least of all. He also quoted growers' reports that King Lear, Elinora, Mrs. S. A. Errey, Black Opal, Champlain, Don Brodman, and Rose Dawn were resistant.

There are several other rather fragmentary reports in the literature but the ones given above indicate that a variation in susceptibility exists although probably no variety is immune.

CURING OF CORMS

SUBERIZATION AND CORK FORMATION: It is now generally conceded that the curing of freshly-dug corms at warm temperatures reduces corm rots. Such curing results in formation of suberin layers and cork cells which, in effect, wall off invading fungi such as Botrytis. Before discussing experiments dealing primarily with the control of the fungus, it seems advisable to review pertinent literature primarily concerning the host.

Artschwager and Starrett (4) studied the rate of suberization and wound periderm formation in cut sections of gladiolus (variety Maiden Blush). Tests were initiated on January 6 and samples were taken daily for the first ten days, then on the fifteenth and again on the twenty-second day. The date of digging and previous storage conditions were described. They found (Fig. 7 adapted from their Fig. 6) that: "At sufficiently high relative humidities the suberization process in the gladiolus goes on normally, beginning in the outermost layer of the corm... and extending centripetally to a depth which is related to the storage temperature and the time of differentiation of the first periderm cells. At the lower relative humidities certain peculiarities were observed. ...At the relative humidity of 75 per cent and a temperature of [54° F.] the outermost layer of cells on the exposed surface remained unchanged. Suberization was only evident below the second or third surface layer. At progressively lower relative humidities the failure of the surface cells to suberize became more marked, and in a lot stored at the relative humidity of 61 per cent and a temperature of [83° F.] as many as four or five layers of cells... did not change so that the suberized zone was more or less buried in the tissue. A similar but even more striking case of 'internal' suberization was observed in certain lots stored at relatively low temperatures for a period of 79 days. The relative humidities and the temperatures at which this experiment was carried out, as well as the results obtained, are shown [in Table 6, which gives the data for only one variety from their Table 1]. It will be seen that the nonsuberized layer was in many instances over 10 cells thick... The low temperature [40° F.], although associated with a fairly humid atmosphere [95 percent relative humidity], probably will account for the great thickness of the nonsuberized layer, which must have dried out somewhat or become otherwise changed before suberization took place."

In regard to wound-periderm they (4) found that "Above 80 per cent, differences in relative humidity neither hastened nor slowed up periderm formation; but below 80 per cent, decrease in relative humidity is shown to have had a retarding influence. The effect of relatively low temperatures on wound-periderm formation is prominent [Table 6]. In a previous section it [was] shown that periderm did not develop at temperatures below [60° F] even after a period of 22 days, so that it might have been concluded that wound-periderm formation was completely inhibited at these temperatures. However, when observations were made after a period of 79 days, it was found that this supposition was only partly true and that a broad wound periderm

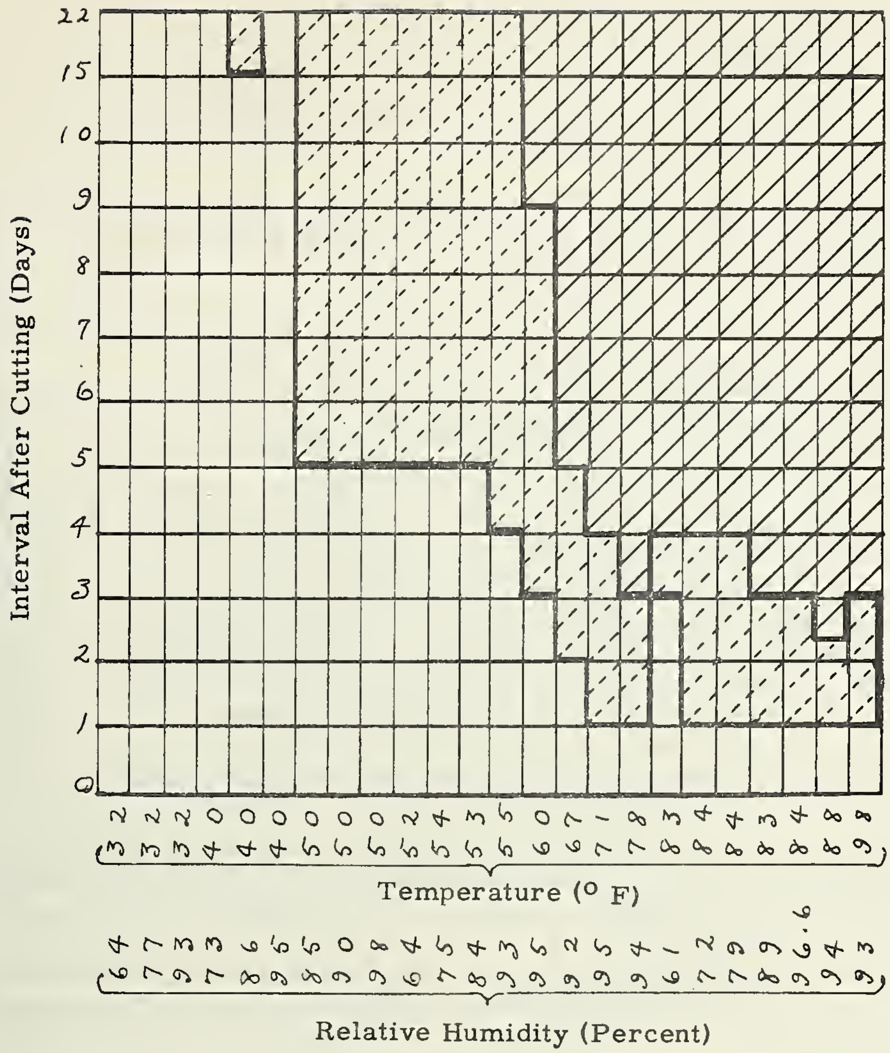

FIGURE 7. Suberization (dotted) and wound-periderm (shaded) formation in gladiolus (Maiden's Blush), January, 1929. (After Fig. 6 from Artschwager and Starrett (4)).

Table 6. Effect of temperature and humidity upon suberization and wound-periderm development in the gladiolus corm (Maiden's Blush). March 1929, 79 days after wounding. (Table 1 from Artschwager and Starrett, (4)).

Temperature	Relative humidity	Thickness of unchanged surface (No. of cell layers)	Thickness of suberized layer (No. of cell layers)	Wound cork
50° F.	85%	6	6	Broad
50° F.	90	2	4	Very broad
50° F.	98	1	6	Very broad
40° F.	73%	20	8	Narrow
40° F.	86	16	8	Narrow
40° F.	95	5	6	Narrow

would develop at [50°] and at [40°] if given sufficient time."

Simmons (67) has recently published a summary of some of his experiments. He found that varieties differ in their formation of cork layers. Some of his comments are: "The importance of this reaction (cork formation) in the curing process, particularly where extensive mechanical injury may occur, is evident. To date inoculation and simple wound studies suggest that it is a natural wound response on the part of the corm and that the fungus exerts little or no influence on it.

"The influence of environmental humidity on wound response of corms of Margaret Beaton and Picardy was investigated. Corms were wounded and subjected to relative humidities of 50%, 75%, and 100%. The temperature was maintained at 85 degrees. The following observations were made:

"(a) Suberization begins at the wounded surface as early as 14 hours after wounding.

"(b) Complete layers of suberized tissue are developed at 48 hours.

"(c) Periderm or cork cells begin to appear below the suberized cells after 3 days and complete cork layers, 1-3 cells deep, develop by the 4th day.

"(d) Both suberization and periderm formation were somewhat retarded at lower relative humidities (50%).

"(e) Corms of Picardy lagged behind those of Margaret Beaton up to at least the 7th day. After this their responses were somewhat erratic and periderm development in Picardy was slower throughout, particularly at 100% relative humidity.

"Observations on stained sections from the inoculated corms showed that at temperatures above 45 degrees a periderm or cork barrier developed and this barrier is probably responsible for the slowing down of the rate of parasitic progress in the corm."

Timmermans (70) stated that the cork layer can be 8 to 10 cells thick. "The hollow corms may also have a cork layer separating the sound from the infected tissue; even the brown vascular bundles are surrounded by corky tissue, contrasting with sound bundles."

RESPIRATION: Whiteman (77) studied "...the relative influence of different storage temperatures on the curing of gladiolus corms as measured by respiration [assuming] that when suberization is well advanced physiological activity is so reduced that the corms may be considered 'cured' and in a resting stage."

He used corms grown near Washington, D. C., dug on October 20 with the tops cut back to 1 1/2 inch and placed in storage October 23. The temperatures used and approximate relative humidities are listed in Table 7.

Table 7. Respiration of corms stored at different temperatures (from Whiteman (77)).

Temperature	Approximate relative humidity	Average respiration in mg. CO_2/kg/hour in milligrams for first two days of curing (4th and 5th day after digging	Respiration in mg. CO_2/kg/hour from 5th to 10th days
32° F.	85%	24	Slowly decreased to about 20
36°	85	29	Slowly decreased to about 23
40°	70	32	Slowly decreased to about 26
50°	75	51	Levelled off near 45 after 5th day
60°	50	81	Slight rise and then rapid drop to 50
70°	40	81	Rapidly decreased to about 46
80°	40	117	Rapidly decreased to about 52

In the first series the corms were cleaned immediately after digging, left in common storage for the next three days, then placed in the various storage chambers. Respiration determinations were made daily for six days. Part of his data are given in Table 7.

As the temperature increased the respiration likewise increased. However, there was a rapid drop within the six-day period, although even at the conclusion of the test the respiration

at high temperatures was approximately double that at low temperatures. The decreased rate was thought to have been due to the advancement of curing or suberization.

In another series, similar corms and storages were used but the corms were not cleaned until November 3 (14 days after digging). The respiration was checked daily from November 5 to November 11 (16th to 22nd day after digging). This, in a sense, was a continuation of the preceding test, with the main difference being the later cleaning of the corms. The respiration rate at the beginning (16th day) was somewhat higher for corms stored at low temperatures than that at the end of the first set, perhaps due to a slight wounding effect in cleaning. (It was noted that corms stored at 50° F and below were difficult to clean on November 3, while others, particularly at 70° and 80°, cleaned easily.) The rate ranged from 20 mg. at 32° to 44 mg. at 80°. By the 22nd day the range was 17 mg. to 24 mg. Although the rate of the high temperature sets had dropped, those of the lower temperatures remained approximately at the same level between the 16th and 22nd days.

In a third series, samples of corms similar to those in the second series were held at the above temperatures until November 30th, then the stems were cut back close to the corms and all were placed at 70° F. A respiration test was started the next day and continued for six days (41st to 46th day after digging). The sets previously stored at 32°, 36°, and 40° F respired very rapidly, in fact even more rapidly than the set in the first experiment stored at 70° three days after digging. The rate for these sets (32°, 36°, and 40°) fell off rapidly to between 39 and 56 mg. on the 46th day. The rate for the 60°, 70°, and 80° F sets remained approximately the same (14 to 26 mg.) throughout the test. Whiteman suggests that the unusually high rate for the low temperature sets may have been due to insufficient suberization, wounding effect, freer exchange of gases through cut stems, or oxidation of accumulated hexose sugars. The rapid decline in respiration of these sets after the first day may have been due to a reversion of sugars to starch.

In another smaller test by Whiteman, the respiration rate was determined for corms that had been dug October 20 and held from October 23 to November 20 at 80° F (cleaned on November 3). One set was left intact. In the other set, all scales and stems were removed. Respiration (which was measured from November 20 to 26) began at 18 mg. and ended at 22 mg. for the intact set; with corresponding figures of 59 and 20 mg. for the other set. As Whiteman stated, "It can hardly be doubted that these corms were cured after 31 days at 80°." He suggested that the increased respiration may have been due to either wound stimulation (by removing scales and stems), or to a freer interchange of gases, or to both.

In an additional small test similar corms held at 70° F from October 23 to December 7 (cleaned November 3) were moved to 32°. The respiration for the next two days averaged 2.3 mg.. On December 10 the corms were returned to 70° F. The respiration rate was 41 mg. on December 11th and 24 mg. on December 12th. The rate of 41 mg. was practically double the rate at 70° at the end of the second experiment.

Denny (26) found that corms stored for a long period in moist soil near 81° F remain dormant but exhibit an unusual type of respiration when removed. "When first removed from the soil after a sojourn in it of several or even a few months, the carbon dioxide production at the temperature which prevailed during the storage in soil is very low, approximately 2 to 10 mg. CO_2 per kg. per hour. This low rate is maintained, however, for only 4 to 8 hours, when the rate rises rapidly until within 24 to 48 hours it reaches 20, 40, 80 or even more than 100 mg. From this maximum the respiration curve falls gradually until after 5 to 7 days the original low rate is reached, this being maintained indefinitely. In spite of this great change in respiratory activity the rest period is not broken, but these corms retain their dormancy, may be again planted in soil and become available for another respiration test. The curve is again given by a subsequent test, provided the period in the soil following the first removal is approximately three months. During the first few hours after removal from the soil (when the rate is low and rising) the volume of oxygen taken in is much larger than the volume of carbon dioxide given off, approximately two to three times as large; but at the time of the maximum rate, and in the entire period during the falling rate, even to the time of the secondary minimum, the volumes of O_2 and CO_2 are equal."

Additional data on respiration and gas (CO_2 and O_2) content of corms are contained in an article by Thornton and Denny (69), and similar corroborative data for breaking dormancy in a 1942 publication by Denny (27).

MOISTURE CONTENT AND LOSS: The average moisture content of freshly dug corms was found by Gault[5] to be 72.8 percent. Corms field-dried and held in a shed for two months until ready to be cleaned contained 62.5 percent. Corms cured at 100°, 110°, and 120° F for 96, 97, and 94 hours, respectively, contained 66.2, 64.5, and 56.2 percent water.

Pridham (62) checked the loss in weight at monthly intervals of Lucette corms (1 1/4 inch diameter) stored at 30° and 60° F. His results were as shown in Table 8.

Table 8. Percentage loss in weight of Lucette corms (1932-33) (from Pridham)

Date	Temperature 30°	Temperature 60°
Dec. 1	6.75	9.20
Jan. 1	6.00	8.56
Feb. 1	10.57	15.89
March 1	10.86	18.01
April 1	11.75	22.39
May 1	19.23	34.16

He suggested that the greater loss in weight at 60°, especially during the last three months of storage, may be due to the production of root initials and apical buds which would result in increased transpiration and respiration.

Cropsey (17) found in drying tests in 1950 at Oregon State College that freshly dug corms (five for each test) lost about 22 percent in weight at 90° F and 50 percent relative humidity within 24 hours, but that it took 72 hours to achieve the same moisture loss at 70° and 50 percent relative humidity. Drying at 90° with relative humidities of 30 and 50 percent resulted in about 35 percent more moisture loss than at 90° with 80 percent relative humidity.

Pommert (60) ran some tests in his warehouse with results as follows: "Recent experiments in our own drying room, using 50 jumbo and No. 1 bulbs of Lady Jane in each lot, indicated that bulbs placed in the direct blast of air with a temperature on the bulbs of 115°, 10% relative humidity (outdoor temperature 66, relative humidity 70%) for 4 hours, had exactly the same weight loss in 4 hours as a like quantity of bulbs dried at 83°, 68% relative humidity, but with accelerated air movement over the second lot of bulbs. The bulbs held for 4 hours at 115° were quite spongy the following day, indicating too much heat, and possibly too low a humidity, rather than too rapid drying. With the 83° temperature as indicated above we can, with freshly dug bulbs, dry and without adhering soil, remove approximately 13.5% moisture, by weight, in 45 hours. If bulbs are wet, or if there is adhering soil, the weight loss will be greater. Our experience indicates that these bulbs are dry enough to go into the storage warehouse provided there is some heat in storage and plenty of circulation and ventilation."

In a recent article Magie (52) has stated that: "Experiments indicate that too rapid drying results in reduction of flower yield, especially with immature bulbs. With rapid movement of air around the bulbs, the temperature should be under 85° F., possibly under 80°. Temperatures over 90° F. should be avoided. The bulbs should not lose more than 20 percent of their weight in moisture during 5 to 7 days of warm curing, according to tests with Picardy variety. Perhaps 20 percent is too high. Rate of moisture loss varies with maturity of bulb, the variety and out-door temperature." He stated in a letter to the writer (February 13, 1953) that he prefers a curing temperature below 90° in Florida because the heating of fresh air to 90° or above would usually result in an excessively low humidity.

Emsweller (32) ran a series of storage tests in 1929/30 at Davis, California. Corms (Prince of Wales variety), about 3/4 inch in diameter, were dug in late October, cleaned and placed in storage on November 6. The percentage loss in weight from November 6 to March 15 was 6 at 38°, 10 at 46°, 12 at 54°, and 20 at 86° F. Corms stored at 86° were somewhat dessicated by February 15 and by March 15 they had sprouted. At intervals Emsweller (32) planted samples of 50 corms each that had been stored at the temperatures listed above. In each

[5] Gault, Ray. (Northern Illinois Public Service Co.). Typed report of 1948/49 experiments made available by Mr. Ralph Pommert, Pacific, Washington.

planting flower production began first from corms stored at 86°. The first series (stored at 86° and planted December 20) began blooming on April 29 and 78 percent of the plants had bloomed by May 13 when the first flower of the comparable 54° set appeared. The second series (86° and January 24 planting) began blooming May 6 and was 98 percent completed by the time (May 19) the first flower of the 54° set appeared. The earliness of the 86° sets persisted even into the last planting series (March 15), but the flowers were fewer and poorer. Only corms of this series that had been stored at 38° gave 100 percent production of good quality flowers. The spikes of all lots except the 46°, 54°, and 86° of the last planting were of high quality. Part of his data on blooming and corm production are contained in Table 9.

Table 9. Effect of storage temperature and time of planting on number of days until first bloom and weight of corms harvested.

Time of planting	Days to first bloom				Weight (grams) of new corms harvested			
	38°	46°	54°	86°	38°	46°	54°	86°
Dec. 20	150	148	144	130	3610	3466	3588	3315
Jan. 24	121	120	115	102	3242	2977	3242	3062
Feb. 15	122	130	117	106	3776	3807	3261	2999
March. 15	112	112	107	102	3670	2410	1979	1743

With freshly dug corms, Forsberg (35) in Illinois reported that adequate drying (as determined by feeling) was accomplished in 16 hours or less (depending upon moisture, etc.) at temperatures of 82° to 104° F. Corms kept well and flowered normally. Forsberg's observations indicated that general warehouse curing was not successful. He adapted a portable forage drier for his large scale tests.

A. N. Roberts of Oregon State College ran curing tests a few years ago, using a small portable prune and nut drier with forced air circulation. He tried 90° F. for 10, 20, 30, and 40 hours; 100° for 7, 14, 20, and 30 hours; and 122° for 7, 10, 13, and 16 hours. He summarized his results as follows in a recent letter (December 22, 1952) to the writer:

"All bulbs, regardless of time factor, dried at 122 degrees F. were cooked or excessively discolored. We were trying for a quick surface moisture removal to save time, but it just does not work that way. It is apparent that some time is needed for certain cell changes, etc.

"In the 100 degrees F. series seven hours and fourteen hours did not give sufficient time to remove sufficient moisture for good cleaning immediately after. However, at both twenty hours and thirty hours, particularly the latter, the bulbs came out in excellent condition, and could have the roots removed right from the drier. The bulbs grew excellently the following year.

"In the 90 degrees F. series, ten hours was not long enough for curing, it was not possible to snap off the root cap. At twenty hours they cleaned nicely as was also the case for thirty hours hours at 90 degrees F. However, the forty hour treatment, while not showing injury, was a little too dry for good cleaning. All this series had excellent appearance and grew well the following year.

"The drying we refer to above is the surface husks, etc., and does not indicate any excessive drying of the bulb itself. The only injury experienced was at 122 degrees F. Of course, there is quite a spread between 100 degrees F. and 122 degrees F. but a temperature of 90 degrees F. was very good as was 100 degrees F., showing a safe spread of temperature in these experiments."

Bald (9) found that corms cured at 95° F were ready to clean within six to seven days, whereas about three weeks were needed at 65° and over six weeks at 55°.

In Gault's[6] experiments corms cured at 100° F for 2, 4, 8, 24, 54, 72, and 96 hours, with relative humidity between 19 and 21 percent, grew well. Those held at 110° for 4, 8, 16, and 24 hours (R.H. 10 to 16 percent) grew well, but the 53 and 97 hour sets (R.H. 13 and 14 percent) were injured. Corms cured at 120° for 2, 4, and 8 hours (R.H. 11 or 12 percent) grew well; for 16 hours (R.H. 12 percent) gave weak growth; while those held for 24, 52, and 94 hours (R.H.

[6] Gault, Ray. op. cit.

14 to 21 percent) did not grow.

Bald (9) stated that curing at 85° F. of corms grown and dug in cool weather encouraged an immediate growth of root initials and buds, which was sometimes prevented by a 95° curing.

In connection with his experiments Simmons (67) stated that, "The use of high temperatures for short periods to speed up curing, now practiced by many large growers, prompted a study of possible effect of high temperature on subsequent behavior of the corm.

"The most striking result of applying dry heat to freshly dug corms appeared to be a tendency to break dormancy. A duplicate trial on old cured corms showed that such corms would withstand quite high temperatures and still sprout. Of those exposed to as high a temperature as 135 degrees for 15 minutes 90% produced shoots."

The writer ran two tests in 1947/48 on the effect of curing on flowering. In the first test corms were dug November 11 and 12 and left in cool storage until November 15, when they were cured for 1, 2, 4, 6, 8, or 10 days at 80° F, returned to cool storage and later planted in the field. Three hundred Surfside and 200 Rosa Van Lima corms (mixed small sizes) were used per treatment. None of the curing treatments affected either earliness of flowering or total number of flowers.

In the other experiment, Picardy corms were dug December 11, washed, cured for 10 hours at 80°, 90°, 100°, 110°, 120°, or 130° F, then stored in a cool (about 50°) room, examined February 7, and planted March 29 and 30. Five hundred corms of mixed small sizes were used per treatment. None of these treatments affected the earliness of flowering or the total production of flowers.

After experiments to accelerate forcing, Loomis (44) came to the conclusion that: "In general, storage treatments of 1 week at 104° F., 2 weeks at 95° F., 4 weeks at 86° F., 6 weeks at 77° F., or 8 to 10 weeks at 68° F. have been approximately equal in their effectiveness on recently dug corms. The lower temperatures with the longer exposures are safer, and milder temperatures should be used for corms already partly through the rest period." Although he does not indicate the digging date, the treating was begun October 28, November 14, or November 17.

EFFECT OF CURING TEMPERATURE ON CONTROL OF CORM ROT: Cropsey (16) found that the loss from rot was greater in corms dried at 65° to 70° for 20 days than in those dried at 95° F for 23 hours, but the amount of rot was small in both cases (4.5 vs. 3.5 percent). Washing and/or turning the corms helped reduce the loss to 1.7 percent or lower in the 95° test.

In a copy of a letter sent the writer in 1951, Cropsey stated that he had obtained best results by curing at 80° to 90° F. from 48 to 72 hours with a relative humidity between 50 to 80 percent using air velocities up to 200 feet per minute, 3 or 4 air changes per hour, turning the corms in order to insure uniform drying and subsequently storing at 50°.

Gould (36) obtained a decrease in Botrytis rot in 1947 by curing J. S. Back corms for 48 hours immediately after digging, as shown in Table 10.

Table 10. Effect of curing treatment on corm rot.

Treatment	Percent of rotted corms
Uncured	18.5
Cured at 75° F	2.0
85°	0.25
95°	0.25

The writer ran several other curing experiments in 1947, in some of which the corms were planted in the field to obtain data on flower and corm yields. The results given in Table 11 indicate that curing for even 12 hours at 75° F decreased the loss from rot, although the amount was unusually low.

In the experiments by the writer in 1947 described in the previous section, corm rot was negligible in the first test. However, in the second the percentage loss was: 20.0 in uncured; 11.4 at 80° F; 14.6 at 90°; 17.2 at 100°; 27.4 at 110°; 23.4 at 120°; and 22.8 at 130°. The loss was reduced at 80° and 90°, but increased at temperatures above 100°. This may have been caused by heat injury.

Bald (13) stated that the fungus remains alive in corm lesions arrested by curing at 95° F.

Table 11. Effect of curing treatment on corm rot.

Variety	Ethel Cave Cole	Beacon	J. S. Bach
Date dug	Probably Oct. 24	Oct. 14	Oct. 23
Began curing	Oct. 25	Oct. 15	Oct. 23
Later storage	Commercial (40-60°)	Comm. (40-60°)	Comm. (40-60°)
Examined	Jan. 13	Jan. 14	Jan. 14
Number of corms per treatment	500	500	400
No. hours cured	27 1/2	See below	See below
Treatment	Percentage of rotted corms		
Uncured	1.6	7.0	18.5
Cured at 75°	0.2	12 hrs : 4.0	24 hrs : 1.5
		24 hrs : 5.2	48 hrs : 2.0
Cured at 85°	0.6	12 hrs : 2.4	24 hrs : 0.8
		24 hrs : 2.8	48 hrs : 0.2
Cured at 95°	0.4	12 hrs : 4.4	24 hrs : 5.5
		24 hrs : 3.4	48 hrs. : 0.2

EFFECT OF WASHING CORMS BEFORE CURING: Hawker (38) did not reduce rot by washing bulbs lifted from wet ground. The writer studied the effect of washing in two experiments in 1947. In the first Picardy corms from plants heavily infected with Botrytis in the Experiment Station plots were dug on November 11, separated into lots of 1000, treated on November 11, stored at approximately 60° F, and checked January 20. Treatment and results are shown in Table 12.

Table 12. Effect of curing and washing on corm rot.

Treatment	Percentage of rotted corms	Condition of corms after curing
Uncured and unwashed	2.5	---
Cured at 90° F (24 hrs) unwashed	0.8	Slightly spongy
Cured at 90° F (24hrs) washed	1.0	Quite spongy

In another test Picardy corms (mixed small sizes from plants heavily infected with Botrytis), dug and supplied by a commercial grower on November 12 were treated immediately, stored afterwards at about 50° to 60° F, and checked January 20 (Table 13).

None of the corms in this test appeared as dessicated as those cured at 90° F in the experiment previously described. These results would suggest that corm condition (water content--?), as well as temperature, play a part in the so-called heat injury.

PREVIOUS RECOMMENDATIONS FOR CURING: Drayton (31) suggested curing at 55° to 60° F and then storing at 40°. Donk and Roggeveen (30) in Holland recommended four to eight days at 80° to 90°, and storage in a well-ventilated barn at ± 60°. Other Dutch (1) recommendations are for curing at 70° to 80° in dry years or with partially dried corms, and 85° to 95° otherwise.

McCulloch and Weigel (55) recommended, for control of Penicillium rot, curing for a week or more at 80 to 90° F immediately after digging and subsequent storage at 35 to 45° with good ventilation and a dry atmosphere.

Crossley and Arrowsmith (19) suggest curing at 75° to 80° F for 10 to 14 days with adequate ventilation, followed by storage at 40° (range of 38° to 45° regarded as satisfactory). They also suggest raising the temperature periodically for a day or two to evaporate accumulated moisture.

Table 13. Effect of curing and washing on corm rot and flowering.

Treatment (500 corms per treatment)		Length of curing (hrs.)	Percentage of rotted* corms	No. flowers by July 10	Total no. flowers
Uncured,	Unwashed	None	3.8	37	51
	Washed	None	1.8	39	51
Washed, dipped in Tersan		None	1.2	27	42
Cured at 80° F,	Washed	41	0.6	40	53
	Unwashed	41	0.6	37	47
Cured at 100° F,	Washed	22	1.4	23	39
	Unwashed	22	1.4	18	36
Cured at 120° F,	Washed	10	5.4	32	50
	Unwashed	10	4.0	34	47

* All types of rot, including heat injury at 120° (turning brown or black) subsequently followed with blue mold.

Bald (12) recommends curing corms immediately after digging in southern California for six to ten days at 95° F with a relative humidity near 80 percent (around corms) and good air movement. After cleaning corms should be replaced at 95° for four to seven days in order to heal wounds, before storing at 40° in a relative humidity between 70 and 80 percent.

STORAGE FOLLOWING CURING: Post (61) stated that "... storage of corms at 40° after curing and cleaning is standard practice among growers. Corms held at this temperature for 60 to 90 days grow rapidly when they are planted. The relative humidity is maintained at 75 to 80 percent with the air circulating freely. ... Storage at 80 to 90° F. for one month before planting is common among greenhouse operators." Yerkes (79) suggested storage at 40° to 45° F. Chase (14) in Florida stated that outdoor curing followed by storage at 38° to 40° was best under their conditions. Grove (37) in Iowa suggested curing in a warm room and then storing at 40° (range of 32° to 50°) and 75 percent humidity.

Rose _et al_. (64) stated that gladiolus ... may be stored at 40° to 50° with a relative humidity of 70 to 75 percent for 7 to 8 months. A temperature of 40° will hold these corms dormant during the normal storage season, whereas at 50° sprouting will occur after 4 to 6 months storage. They should be stored dry in shallow trays with ample ventilation but only after a curing period of 3 to 6 weeks in an open or well-ventilated shed."

Fairburn (33) found that storage of corms (variety Giant Nymph) from October 18 to February 8 at 50°, 70°, and 90° F resulted in 4.2, 5.2, and 15.7 percent loss in weight, respectively. Corms stored in an open tray in a laboratory at 77° for 200 days lost 32 percent, of which 55 percent occurred within the first three weeks after harvesting. Giant Nymph glads were dried for three days at 77°, transferred to 50° until December 8, and then stored at 32°, 41°, and 50° until planting on May 8. Corms held at 50° produced the most spikes, earliest flowers, and greatest number of new corms. He also found that higher temperatures (up to 90°) produced excellent early spikes under greenhouse forcing conditions, but indicated that the results did not necessarily apply to the field.

Fairburn also found that an early flowering variety (Souvenir) respired more rapidly than did a late one (Giant Nymph) and suggested that optimum storage temperatures for the two might be different. For instance, early varieties would be benefited by moderately low storage temperatures to reduce the combustion rate of plant foods, whereas late maturing varieties might benefit from higher temperatures that would increase the respiration rate and shorten the dormant period.

Pridham and Ratsek (63) made a rather thorough study of storage temperatures as they affect flowering and corm yield. They used several varieties, but the most common one was Lucette. Corms were harvested from October to November 15, dried, cleaned, and placed in storage in November. Five sizes were used, as indicated in Table 14. For the 1 1/4 inch size,

Table 14. Experiments with the variety Lucette (from Pridham and Ratsek).

Storage temperature (°F)	Corm diameter (inches)						
	1.25	1.00	0.75	0.50	0.25	High Humidity 1.25	Low Humidity 1.25
	Percentage Weight Loss by Corms in Storage (November-April)						
32[a]	14.82	19.93	23.45	27.57	30.44	6.00	26.00
40	10.46	14.84	16.36	18.84	21.62	5.00	27.00
50	18.67	27.35	28.08	27.24	27.88	4.00	30.00
60	26.62	25.10	26.69	26.39	32.69	13.90	33.33
70	38.63	34.02	28.27	31.96	36.18	---	47.00
	Number of Days from Planting to Bloom						
32	115.2	113.2	112.3	113.7	119.9	114.0	118.7
40	112.8	110.0	110.8	111.5	115.9	108.2	113.1
50	111.4	107.8	109.3	111.2	118.3	105.7	109.8
60	108.0	113.3	116.3	116.4	120.0	112.7	107.5
70	108.3	101.9	101.5	111.7	120.4	82.2	107.5
	Number of Flower Spikes per Corm Planted						
32	1.80	1.36	0.95	0.85	0.68	1.23	1.55
40	1.75	0.95	0.99	0.93	0.92	1.13	1.05
50	1.38	0.99	0.96	0.97	0.83	1.05	1.30
60	1.10	1.03	0.95	0.94	0.59	0.98	1.13
70	1.13	1.06	0.83	0.93	0.92	0.55	0.30
	Number of Corms Harvested per Corm Planted						
32	2.10	1.481	0.98	0.88	0.73	1.40	1.72
40	1.80	0.980	1.02	0.97	0.97	1.15	1.20
50	1.53	1.104	0.99	0.96	0.87	1.05	1.37
60	1.38	1.040	0.99	0.97	0.66	1.15	1.20
70	1.35	1.286	0.96	0.81	0.86	0.70	0.75
	Yield of Corms as Percentage of Weight of Corms Planted						
32	156.5	230.1	278.2	428.3	694.0	148.8	192.8
40	200.0	197.9	367.6	534.8	1066.2	136.3	215.8
50	145.5	200.2	307.6	473.1	967.0	123.9	200.2
60	167.5	206.9	319.1	472.2	723.5	154.9	210.0
70	183.8	289.6	409.6	642.9	1289.8	151.5	117.5

a 30° is listed in the reference (63) but the refrigerator was actually set at 32° according to a letter (September 25, 1953) from Pridham.

four samples of 10 corms each were used; for 1 inch, 3/4 inch and 1/2 inch, ten samples of 25 corms each; and for 1/4 inch, four samples of 25 corms each. Humidity trials were made also with the largest corms, with one sample suspended over water (near 100 percent relative humidity) and the other over calcium chloride (about 10 percent relative humidity), both in closed containers. The average temperatures and relative humidities were: 32° F., 70 percent; 40°, 80 percent; 50°, 50 percent; 60°, 60 percent; 70°, 30 percent. The corms were removed from storage on April 15, weighed and examined, planted in pots and grown in the greenhouse for one month, then transplanted into the field. Plants were dug October 1, dried for a week, then cleaned, counted and weighed. Data for the variety Lucette are contained in Table 14.

The results seem to be more consistent with the largest corms than with the smaller ones. With the former the percentage of weight loss was least at the low temperatures and increased as the temperature rose to 70° F; the number of days to bloom, the number of flower spikes per corm, and the number of corms harvested per corm planted decreased as the temperature increased; yield of corms as a percentage of weight of corms planted had two peaks, one at 40° and the next highest at 70°. The detrimental effect of low humidity was more noticeable at high than at low temperatures on loss of corm weight.

In additional tests with nine other varieties, Pridham (62) found that the large corms gave more consistent results than did small ones. Low temperature storage induced delay in flowering but resulted in maximum flower spike production.

Ryan and Ulman (65) stated that at the University of California at Los Angeles, "A doctoral dissertation by George F. Ryan reported that the rest period of deeply resting corms was prolonged in some cases (but not all) by exposure to high temperatures (95° F.) either during a curing period or during storage. Corms stored at 34 to 39° F. had a considerably shorter rest period than corms stored at 70 to 95° F. Brief exposure to the latter temperature did not interfere with the rest-breaking influence of the low temperature. Corms which reached maturity with soil temperatures above 59° F. had a somewhat more profound rest than corms which were exposed to temperatures of 50° F. for the equivalent of several days during the final weeks before harvest."

Lauritzen and Wright (43) ran storage tests in three different years, using several varieties at different temperatures and ranges of relative humidity including: 32° F. (64 to 93 percent R.H.); 40° (72 to 95 percent); and 50° (81 to 98 percent). In general they found that the lower the humidity the greater the weight loss. Surprisingly enough they obtained more loss at 32° than at 40°, presumably owing to the lack of suberization at the lower temperature. Most corms remained dormant at 32°, at 40° some rooting was present, while at 50° both sprouting and rooting were common, particularly at the higher humidities. The average (of three humidities) moisture loss was 8.2 percent at 32°, 7 percent at 40°, and 8.2 percent at 50°. There was considerable difference in weight loss among the different varieties. In general the total corm yield increased as the storage temperature dropped from 50° to 40° to 32°, but the largest yield of #1 corms was often greatest near 40° F. The optimum humidity at this temperature varied for corm yield with the variety. Similar tests showed that the different humidities did not seem to affect flower production nor the total germination. Data given for 1928-29 indicated that storage near 32° retarded emergence. In connection with studies on infection by *Penicillium gladioli*, they decided that temperature was more important than humidity in limiting or promoting suberization and periderm formation.

Weinard and Decker (73) reported an experiment by Floyd in which "...gladiolus corms were stored in an open shed in Florida and also placed for periods as long as four months in cold storage at 32° to 35° F. and at 42° to 45° F. before planting in the field. Corms stored at 32° to 35° F. came up and also bloomed about a week later than did corms stored at 42° to 45° F. The length of time the corms were in cold storage seemed to make little difference in the results. There was no marked difference in results with corms stored at 42° to 45° F. as compared with corms stored in the open air."

Weinard and Decker (73) stored corms in 1925 for 9 to 13 weeks at 38° and 70° to 80° F, then forced them in a greenhouse. The corms from warm storage sprouted 5 to 18 days sooner than those from cold storage and flowered slightly earlier, but the percentage of corms flowering was inconsistent.

Magie (52) made the following comments in 1952: "In a test comparing 92 percent with 70 percent relative humidity in 40° F. storages, there was little difference in results with Picardy or Snow Princess bulbs, except that immature bulbs produced better flowers after storage at 92 percent humidity. The lower humidity favored flowering of mature Snow Princess bulbs and increased the number of sprouts that grew from each bulb. Storage humidity probably has a minor effect on bulbs, provided it is not so low as to cause excessive water loss or high enough to

cause root growth. The evidence at hand indicates a relative humidity of 80-85 percent is best for 40° storage if the temperature does not fluctuate and moisture does not collect on bulbs. At higher temperatures, lower humidities may be necessary to avoid sprouting."

Lauritzen and Wright (43) obtained no particular difference in emergence or flowering of corms stored at 40° F from November 18 to March 17, then placed at temperatures ranging from 54° to 99° F for ten days, and next forced in a greenhouse.

Denny and Miller (22) found that low storage temperatures (37° and 50°F) were more effective in shortening the rest period than were higher temperatures (64° to 77°, 84°, or 95°) for periods of 28 to 97 days. Denny (23) obtained much earlier germination in all varieties tested with corms placed for six weeks at 37° and 50° ten days after harvest than with those stored at 86° and 95°. With corms held at room temperature (about 72°) for 52 days before being placed in storage, the temperature effect varied with the variety, low temperatures being optimum for such varieties as Dr. F. E. Bennett and high temperatures for Souvenir. Samples of 18 to 35 corms were used in these tests.

Denny (26) summarized the results of additional studies (24, 25) on respiration and rest periods as follows in 1940: "Although gladiolus corms when freshly harvested are dormant, they pass through this rest period, usually in one to three months, and then will germinate promptly when planted. This rest period may be prolonged for many months or for two years or more with certain varieties by the simple expedient of replanting the freshly harvested corms in moist soil and storing at room temperature or preferably at about 81° F. With the passage of time, corms with a rest period artifically prolonged in this way become sensitive to low temperatures, such as 32° and 41° F. Germination can then be induced by short periods of chilling such as 48, 24, 12 or even 6 hours, depending on the variety and the duration of the period of enforced rest at the time of the exposure to cold."

EFFECT OF STORAGE ON DISEASE CONTROL: Cropsey (17) inoculated corms of Picardy with Botrytis and Fusarium, held them for 48 hours at 58° F and 98 percent relative humidity, next cured them at 95° for 24 hours, and then placed samples in storage at 40°, 50°, or 60° from October 16 to March 22. The total loss from rot was as shown in Table 15. He concluded

Table 15. Percentage loss from corm rot (from Cropsey)

Inoculated with	Loss (percent) at indicated storage temperature (° F)		
	40	50	60
Botrytis	76	24	54
Fusarium	27	86	99
None	1	11	16

that 50° was the best all-round temperature. Although no comparable checks were made at common storage temperatures, it would appear from a comparison of inoculated and noninoculated data that 24 hours at 95° did not provide adequate curing. The high loss from Botrytis at 60° is also interesting in view of tests by others, which would indicate that this temperature should be too high for much infection to occur.

VENTILATION IN STORAGE: Magie (52) has stressed the need of proper ventilation in storage, particularly with freshly-dug corms. "Bulbs have been killed by lack of aeration in storage. Usually the injury caused by confinement shows up as a white pitting or chalky pit. White, chalky tissue also develops at the site of bruises if ventilation is poor. Other symptoms of poor aeration are scald of bulb surfaces, blackening of root traces, multiple sprouting, and activation of latent Fusarium infections after planting. There have been several clear-cut cases of severe losses from Fusarium brown rot, in resistant as well as susceptible varieties, as a result of accumulation of toxic gaseous by-products from physiologically active bulbs in transit or in storage that became warm and moist. Many instances of shipped bulbs rotting badly after being planted by the customer can be explained by improper ventilation in curing or shipment of bulbs."

CONTROL

CURING: Warm temperature curing, regardless of whether it is performed under natural or artifical conditions, results in a number of more or less related changes in the corm. First, and most obvious, is the loss of water; second is the deposition of suberin in one or more layers of cells; third is the formation of cork layers around wounds, etc. and the abscission layer at the base of the new corm; and fourth are various other physiological processes as shown by respiration tests. (The formation of the abscission layer at the base of the new corm cuts off the old one, prevents excessive drying and retards fungus invasion.)

When harvesting is done during warm weather such as usually occurs in the Midwest, Florida, and similar areas, normal temperatures should promote adequate curing. However, artificial curing must be resorted to under cool moist conditions such as normally occur in the Pacific Northwest and often elsewhere.

The few pertinent tests that have been made indicate that curing should begin soon after digging. From available data it appears that a temperature range of 85° to 95° F should be optimum, but the condition of the corm should probably dictate the choice of temperature. Higher temperatures may result in more rapid curing but may also result in heat injury, especially to immature corms. The humidity is also very important and some of the injury previously encountered at temperatures such as 90° to 95° may be due to excessively low humidity. The relative humidity apparently should be about 80 percent around the corms. Between stacks of trays it may be lower.

The practical application should not be overlooked. For instance, Pommert (60) has come to the conclusion, after considering both the cost of fuel and loss from corm rot, that a temperature of 75° to 80° F is the most satisfactory under his conditions.

Some growers have attempted to warm up their entire warehouse for curing purposes. This has not ordinarily been successful. Most growers have used one or more rooms specifically for the purpose. The location of the heater and fan and arrangement of trays should be examined by an agricultural engineer, or the grower should check with an accurate thermometer the temperature in all parts of the room when filled with bulbs, and check the air circulation with a smoke generator. Too often a stratification of air exists with the possibility of the upper corms being overcured and the lower ones undercured.

The small grower often has difficulty obtaining the proper curing conditions. He can sometimes use a furnace room (although it would seldom reach a temperature of 85° F) by putting up temporary partitions, hanging tarpaulins, etc. A fan should always be used in order to circulate air adequately.

Krone (42) made an interesting suggestion for the small grower, namely, the use of infrared heat bulbs as a source of heat. They should be supplemented with a fan.

Thermostatically controlled electric heaters are an excellent possibility for the small grower. The writer has used one type (Thermador, 3000 KW, 220 volts, with the fan bypassed so it runs continuously) for five years in his experiments, with variation in temperature of approximately $\pm$ 1.5° F.

In order to maintain the proper temperature and relative humidity, a thermometer and humidity indicator should be kept constantly in the curing room as well as in the warehouse.

<u>When is a corm cured?</u> -- Some workers have suggested that the amount of moisture lost is the best indicator. Although that may be true, it would seem more practical to use the formation of the abscission layer (when the old and new corms separate easily) as the criterion.

Under conditions in western Washington, artificially cured corms can be cleaned sooner than is usually the case, but unless done immediately cleaning becomes increasingly more difficult. This may be made somewhat easier by overnight covering with a damp sack.

Hawker (38) obtained less rot in corms that were cleaned early and completely than in those cleaned more than a month after digging and only partially.

<u>How long to cure?</u> -- This will depend upon the temperature and relative humidity used, condition of corm, number of corms per room, etc. Corms grown under very moist and cool conditions are more "succulent" and probably require a longer time than those grown under drier conditions. Seven to ten days is often sufficient. These more succulent bulbs also may be more susceptible to heat injury.

<u>Curing after cleaning?</u> -- Bald's (9) tests indicate that curing again at 95° F for four days after cleaning facilitates suberin and cork formation in the wounded base, thereby decreasing

opportunity for fungus invasion.

STORAGE: Judging from the available data, there seems to be considerable merit in storage temperatures of either 40^{o} or 50^{o} F, but 40^{o} would seem to be somewhat better. The optimum humidity is still unknown, but the limited data indicate that a relative humidity between 70 and 80 percent may be best.

Even cured corms are constantly losing moisture and accumulation on the surface during storage may permit growth of various fungi. Therfore, the suggestion made by certain workers of raising the temperature periodically in the warehouse in order to evaporate condensed moisture seems logical. The frequency with which this should be done, the optimum temperature to use, and the duration of the heating periods, are problems for investigation.

FUNGICIDAL DISINFECTION OF CORMS: The fungicidal disinfection of corms to control various rots has probably received more attention than any other means of control. Some tests have been made immediately after digging (labelled "pre-curing" below), some after cleaning ("pre-storage") and some just prior to planting ("pre-planting"). The following experiments were particularly concerned with Botrytis control.

<u>Pre-curing</u> -- Hawker (38) reduced the rot slightly in a small scale test by dusting corms immediately after digging with pentachloronitrobenzene.

Wade (72) reduced corm rot from 47.5 percent in the untreated set to 8.4 percent in sets dipped for 15 minutes in Hortosan D.P. (an organic mercury compound) at digging time. Other mercuries including mercuric bichloride were good but not quite so effective.

<u>Pre-storage</u> -- Davidson (20) reported some pre-storage experiments by Davis, who used seven materials on more than 12,000 corms without obtaining any appreciable reduction of rot.

White (76) stated in 1946 that Botrytis rot of corms in Tasmania was effectively controlled by descaling ten days after digging and then treating with tetroc or Spergon.

Hawker (38) reported some unpublished data by Burrows, who obtained a reduction of rot during storage from 23.8 percent to 2.5 percent and 7.0 percent by treating with pentachloronitrobenzene (p.c.n.b.) and Brassisan, respectively. Hawker also obtained promising results with p.c.n.b. but had better control with a 20-minute, 1-hour or 3-hour soak in 0.1% mercuric chloride. The latter did not adversely effect plant growth in 1942 or 1943, but did in 1944.

Bald (12) suggests dusting or dipping with Arasan, Spergon, or some other mild fungicide.

<u>Pre-planting</u> -- In contrast to the benefit from mercuric chloride over p.c.n.b. as a pre-storage treatment was the treatment at planting time, when the p.c.n.b. gave superior results in a small scale test by Hawker (38). She attributed this to the more rapid leaching of mercuric chloride from corms in the soil. The p.c.n.b. did not affect flowering or corm yield.

According to Magie (47) Botrytis corm rot following planting "...was controlled in the Maid of Orleans variety by treating the corms at planting time in a 2 percent suspension of Tersan, in phenyl mercury oleate 1/8 percent, in Ceresan M 1/8 percent + Tersan 1/2 percent, in Dow 9B 1/2 percent, or in Ceresan M 1/4 percent. The last treatment was a 10-second dip. In the other treatments the corms were soaked for five minutes. These treatments doubled the yield of flowers and corms as compared with untreated."

Comeadow (15) stated in 1948 that in Australia Botrytis blight and rot (as well as dry rot and hard rot) had been effectively controlled by a 48-hour immersion of the corms before planting in a solution of Keotized mercury E (an animal oil emulsion of phenyl mercuric acetate, 1 ounce in 1 1/2 gallons of water). However, he suggested that freshly dug corms should be dipped for only 15 minutes.

Bald (11) found that New Improved Ceresan (2 lb/100 gal) gave better control of the neck rot phase of <u>Botrytis</u> than Lysol or ferbam. In one trial it also gave significant reduction in <u>Botrytis</u> lesions on the daughter corms. He (12) recommends a 30-second dip for trial in place of the standard 15-minute soak in view of results by Young, who showed that less mercury injury may occur. Well-cured corms are probably less injured by chemicals than others.

The writer has also run some disinfection tests before and after cleaning and just before planting. Although there was a slight reduction in the loss from Botrytis rot, it appeared that curing alone was sufficient and most practical under western Washington conditions. Corms are dipped in thiram before planting, but for the control of dry rot.

CORMEL TREATMENT: Most trials with fungicides have been made on corms. Those made on cormels by the writer and by others have usually given disappointing results, regardless of the disease concerned. However, Bald recently (12) briefly described a method developed by Roistacher and Bald whereby all diseases and pests except bacterial scab and virus diseases had been eliminated from bulblets. This method consisted of the following steps: elimination of mummified bulblets; presoaking others overnight in water at room temperature; 30-minute soak in water at 135° F; removal and cooling by plunging into cold water; drying and storing as usual. This treatment must be applied when the cormels are fully dormant. Roistacher has perfected a test with tetrazolium chloride for this purpose. Twenty cormels are split and placed in a 1% solution of tetrazolium chloride in the dark at 70° for four hours. If they are fully dormant they are not stained at all or only stained a light pink. As they become less dormant the intensity of the red color increases, although the rate varies with the variety. (They also stain red immediately after being dug, but this is an indication of physiological activity and not of capacity for germination.)

PLANTING LOCATION: Soil type -- As Hawker (38) has pointed out, the loss is often greatest in the heavier soils and/or soils that are apt to be quite wet, especially late in the season. Peiris (59) obtained percentage losses of 24% to 47% in corms grown in dry soil vs. wet soil under otherwise similar conditions.

Rotation -- The longevity of the organism in the soil, in gladiolus debris, and as independent sclerotia is unknown. Three years might be sufficiently long to permit the fungus to die out. Ordinarily the persistence of dry rot and Fusarium rot would prevent a quicker return to the same location.

Soil treatment -- Hawker (38) tried formalin, mercuric chloride, Uspulun, Aretan, Brassisan, and pentachloronitrobenzene as soil treatments without benefit.

Magie (50) suggested the following practices to prevent the formation of sclerotia: "Burn or bury a foot deep all infected material including bulbs, spikes, florets and leaves. On larger plantings where removal of diseased tops may not be feasible, broadcast 500 pounds calcium cyanamid per acre, then cut leaves immediately after bulb harvest and plow trash under completely."

PLANTING DATE: In order to take advantage of the reduction in rot by digging somewhat early, it is necessary to plant accordingly. Also, the most susceptible varieties should be planted first, followed by those with more resistance.

ROGUING: Hawker (38) obtained less rot in storage in lots that had been carefully rogued in the field, than in those less carefully rogued.

The prompt removal of spikes from the field is particularly important, since flowers are more susceptible than any other part of the plant to Botrytis attack and act as "breeding grounds" for the formation of huge numbers of spores. Spikes should be cut as tight as practicable. Unused ones should be dumped in a distant location, or preferably, in a pit and covered with dirt, lime, or some fungicide to discourage sporulation.

DIGGING: The data and observations previously reported demonstrated that stocks dug early usually develop less rot than those dug late. Naturally it is not feasible to dig all corms early, but that should be the goal as far as possible, particularly with the most susceptible varieties.

On the other hand, observations also indicate that it is often better to delay digging rather than to dig during rain. This, too, is not always possible but digging should be attempted in the driest weather possible.

Although the limited data available do not support the policy of washing corms before curing, the writer believes that washing has merit if a considerable amount of mud adheres to the corms at digging time, as most often happens in silt type soils. Some growers' results support this belief.

Peiris (59) decided that there was no advantage to breaking off the tops of corms immediately after lifting as recommended by Timmermans, except in special cases.

SPRAYING; Wade (72) controlled leaf spots by spraying at weekly or biweekly intervals with Bordeaux, but there was no reduction in corm infection. Bordeaux (plus a wetting agent) has since been recommended (2) in Australia.

Magie (49) was apparently the first to demonstrate the effectiveness of various carbamates in controlling Botrytis blight and flower spot of gladiolus, and such sprays have been successfully used since 1947 by Florida growers. He suggests using 2 quarts nabam (Dithane D-14, Parzate Liquid, etc.) plus 3/4 lb. zinc sulfate (monohydrate powder, 36% zinc) plus 3 to 5 ounces Triton B 1956 per 100 gallons of water; or zineb (Parzate, Dithane Z-78, etc.) which is the prepared zinc salt of nabam. It is a wettable powder and does not require mixing with zinc sulfate. Two pounds are used in 100 gallons, plus 2 ounces of Triton B 1956. The nabam spray will leave less residue than the zineb. Either material will burn the edges of open petals. Magie (50) recommends that spraying begin three weeks earlier than the earliest recorded outbreaks of Botrytis in the area. He suggests one spray per week during dry weather and two or three sprays per week when the disease appears in the vicinity, in order to protect foliage. However, spikes should be sprayed every day in wet weather, otherwise every second or third day since they are constantly growing and exposing new tissue. These fungicides will also control Curvularia and Stemphylium.

Holloman and Young (39) obtained definitely better control with weekly sprays of ferbam (2 pounds per 100 gallons) than with Phygon XL, Puratized Agricultural Spray, or Crag Fungicide 341C, and slightly better than with nabam in Oregon. They recommend ferbam where sale of cut flowers is not involved and nabam if it is a factor.

Manzate has also been reported promising for Botrytis control on gladiolus (12).

TREATING CUT SPIKES: Magie (49) has stated that Botrytis can be effectively controlled on cut flowers without injury by dipping cut spikes for two seconds in a solution of 1 pint of Puratized Agricultural Spray per 100 gallons of water with enough wetting agent added to make a film on the petals. Such a dip will, of course, only destroy spores on the surface and cannot eradicate infections already present.

Recently (December 9, 1952) he informed the writer that a 2- 5-second dip in the regular spray mixture of nabam plus zinc sulfate was also effective in disinfecting cut spikes and did not injure the petals if flowers were cut in the tight bud stage. Vancide 51 was effective when used in the same manner at spray strength.

Bald (12) reported that dusting spikes with Mathieson 275 (pentachloronitrobenzene) checked the infection.

Fischer and Keller (34) found that Botrytis infection of gladiolus flowers in a closed container could be controlled by placing brominated activated charcoal around the spikes. They assumed that bromine was released slowly and acted as a fumigant.

SUMMARY

Botrytis now rates as the number two gladiolus disease in the United States. Its development is dependent upon cool temperatures and high humidity, conditions which are most often encountered on the Pacific Coast and in Florida. It is usually caused by B. gladiolorum, but occasionally by B. cinerea, B. elliptica, and perhaps B. gladioli. All parts of the plant may be infected, resulting in flower blight, leaf spot, neck rot, and corm rot.

Basic control measures are now known, although refinements on some are needed. The main controls are:

1. Planting in a location with good soil and air drainage.
2. Roguing of diseased plants and removal of old flower spikes.
3. Spraying periodically with nabam, ferbam, or zineb sprays during weather favorable for the fungus.
4. Digging as early and in as dry weather as possible.
5. Heat-curing promptly at 85° to 95° F with a relative humidity of about 80 percent for seven to ten days, cleaning and returning to the curing chamber for four to seven days more.
6. Storing at 40° to 50° with a relative humidity of about 70 to 80 percent.

More information is needed on the optimum temperatures and relative humidity for both curing and storing, particularly in relation to condition of the corm. Experiments under way by Dr. Neil Stuart (U.S. Department of Agriculture, Plant Industry Station, Beltsville, Maryland) should yield information on these points (See Addenda, 1).

ADDENDA

1. A manuscript summarizing the results to date has just been received from Dr. Stuart, et al. It is being released for publication to the New England Gladiolus Society and North American Gladiolus Council under the title, "Preliminary report on effects of curing, storage temperature, and relative humidity on flowering and corm production of gladiolus."

Stuart, et al., point out (a) the need to distinguish between heat-drying and heat-curing; (b) the need to distinguish the physiological effects of drying, curing and storage of gladiolus corms on their growth and production as opposed to their effects on disease organisms attacking the corm; and (c) the many factors that influence growth and response of gladiolus corms. (For instance, in one of their experiments "...small corms harvested from cold soil in November dried out rapidly and ultimately died when the relative humidity was maintained at 50 percent and the temperature at 40°. Larger corms harvested earlier and cured in a warm room were not damaged by the same storage conditions.")

They state that "There is some evidence in our tests that low-temperature storage favored multiple-sprout production while slightly higher storage temperature resulted in production of fewer spikes of higher quality and fewer new corms." (40° vs 50° F). They then raise the question as to whether this is caused only by higher temperatures favoring growth of Fusarium or if there is also a direct effect on growth of the plant.

Corms that were stored at 40° F with a relative humidity of 50 percent contained only 13.5 percent moisture at planting time and failed to grow when planted. Others had 21.3 percent moisture at 35° and 70 percent humidity; 52.9 percent at 40° and 85 percent; and 51.3 percent at 50° and 90 percent. Heat-treatment (10 days at 90°) just before planting accelerated blooming.

Until additional information is obtained, they advise gladiolus growers: "... to avoid temperature extremes during curing and storage and to prevent excessive drying of the corms while they are in storage."

2. In connection with experiments on the Fusarium disease, Barton H. Marshall, Jr. recently reported (Relation of wound periderm in gladiolus corms to penetration by *Fusarium oxysporum* f. *gladioli*. Phytopath. 43: 425-431, 1953), "...that rapid drying at high temperature aids in preventing infection by *Fusarium*, and that the high humidity during the curing period is not only non-essential but may be quite undesirable." These results refer mostly to 95° F and 95 percent relative humidity, although other temperatures were tested. Under his conditions, the Fusarium-infected portion of the corm was not completely walled off, even at 95°.

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